Coastal Contamination Migration Monitoring

NFESC

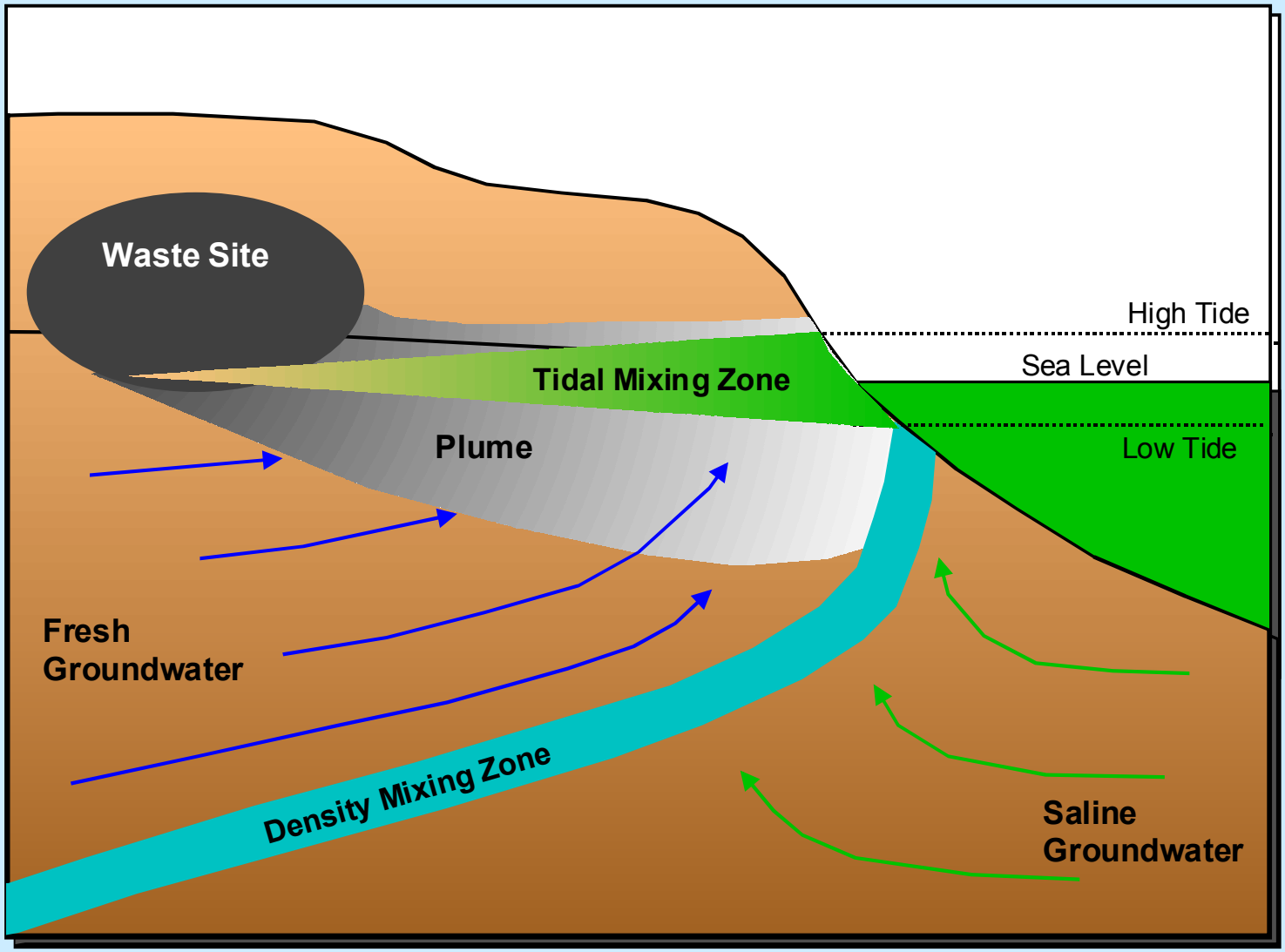
SPAWAR Systems Center – San Diego

NAVFAC

Presentation Overview

- Background
- Technologies
- Information Resources
- Summary and Conclusions

Contaminated Groundwater Discharging to a Surface Water Body



Scope of the Navy Problem

- Cleanup of sites with landfills/plumes located adjacent to harbors, bays, estuaries, wetlands, and other coastal environments
- A recent Navy review indicates potential for groundwater–surface water interaction at a large number of coastal landfills and hazardous waste sites

EFA/EFD	Groundwater Contamination	Tidal Infiltration	Groundwater Infiltration
Atlantic Division	29	14	16
EFA Chesapeake	14	4	10
EFA Northeast	20	10	18
EFA West	29	14	31
Southwest Division	19	15	13
EFA Midwest	3	0	3
EFA Northwest	6	8	10
Pacific Division	5	10	8
Southern Division	27	26	50
TOTALS	**152**	**101**	**159**

Background

- Technologies are lacking for assessing the containment of contaminants within coastal landfills and hazardous waste sites
- Sites are currently assessed on the basis of onshore wells and hydrologic models which provide limited information on actual containment and are difficult to verify
- New technologies have been developed to improve our ability to assess flow and contaminant detection

Technology Selection

Will the technology provide an accurate measure of containment, migration, or exposure at the site?

- Temperature/Conductivity/Pore-water Probe (Trident® Probe)
- Ultrasonic Multi-Sample Seepage Meter (UltraSeep Meter)

Potential Technology Impact

Current Practice

- Sites are currently assessed on the basis of onshore wells and hydrologic models which provide limited information on actual containment and are difficult to verify

Current Cost

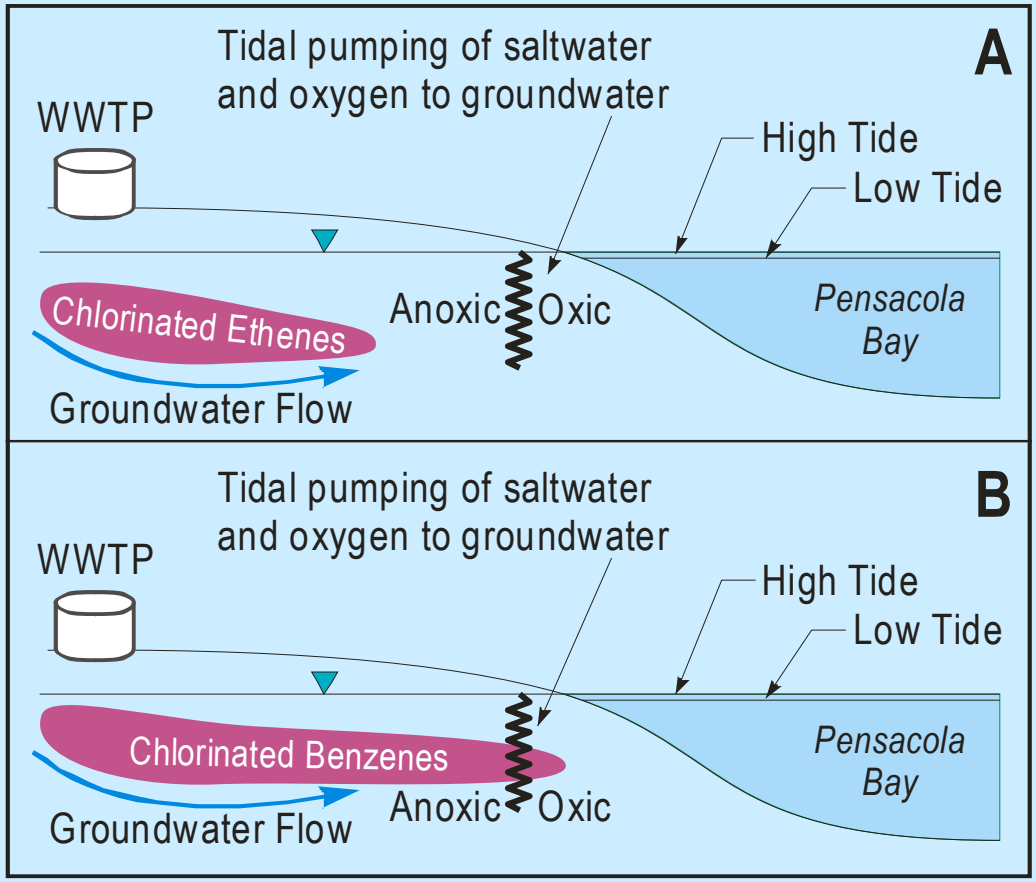
- Approximately $200K-$300K or greater for installation of wells, analysis, and modeling of results
- Modeling results are often not accepted due to uncertainty

Potential Cost Savings

- Approximately $400K minimum by avoiding an inappropriate or unnecessary remedy at a site

Potential Technology Impact (cont.)

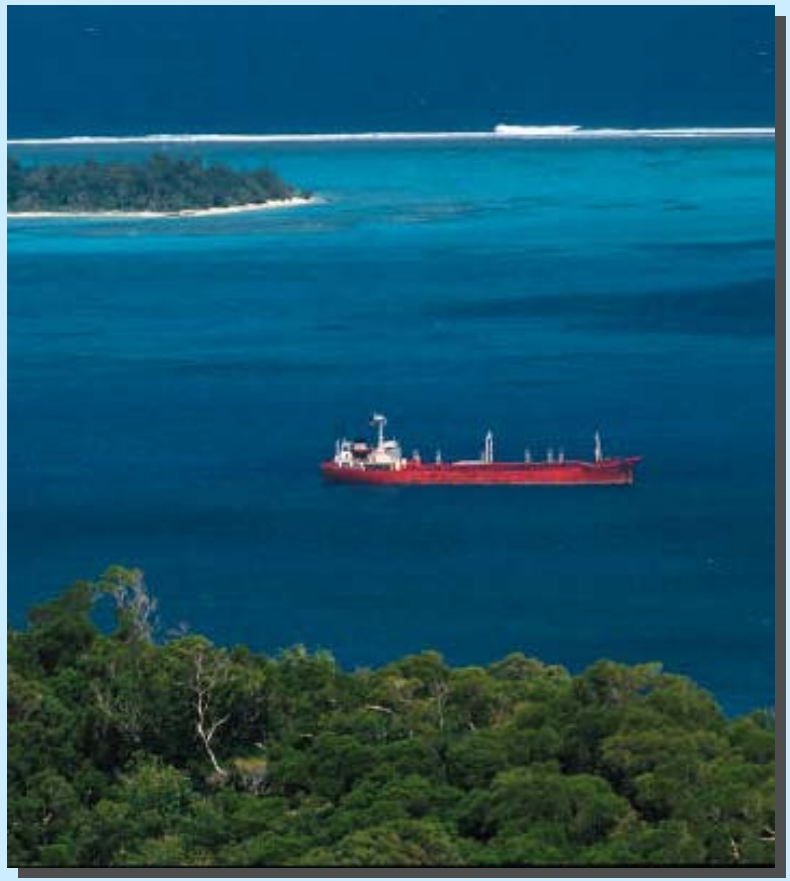
- Improved site knowledge leads to selection of more appropriate, less expensive remedial alternatives
- NAS Pensacola utilized a combination of in situ chemical oxidation for source reduction, and monitored natural attenuation for final remedy based on assessment of attenuation capacity due to tidal pumping of the shoreline aquifer
- Estimated cost savings ~$2,000K



- Observed anoxic degradation of chlorinated ethenes in groundwater
- Inferred oxic degradation of chlorinated benzenes where oxygen is delivered to groundwater by tidal pumping

When Should These Technologies be Applied?

- If there is clear identification of a terrestrial contaminant plume migrating to the shoreward boundary of the surface water body
- If ARARs or other compliance/ cleanup drivers require identification of contaminant exposure levels in the surface water or at the interface



When Should These Technologies be Applied? (cont.)

- If hydrogeologic modeling results are ambiguous, or require field validation
- If the area where the plume is impinging needs to be clearly delineated to address risk and/or remedial options (Trident)
- If the rate of discharge and associated contaminant loading requires delineation to address risk and/or remedial options (UltraSeep)

Estimated Trident® Application Costs

- Trident – assumes shallow water deployment (no diving), 30 stations, water analysis for VOCs

Study Component	Estimated Cost ($K)
Sampling and Analysis Plan	5
Field Sampling	10
Sample Analysis	4
Data Analysis and Reporting	6
Totals	25

Estimated UltraSeep® Application Costs

- UltraSeep – assumes diver deployment at 4 stations, 24 VOC samples (6 per site)

Study Component	Estimated Cost ($K)
Sampling and Analysis Plan	5
Field Sampling	20
Sample Analysis	4
Data Analysis and Reporting	6
Totals	35

Presentation Overview

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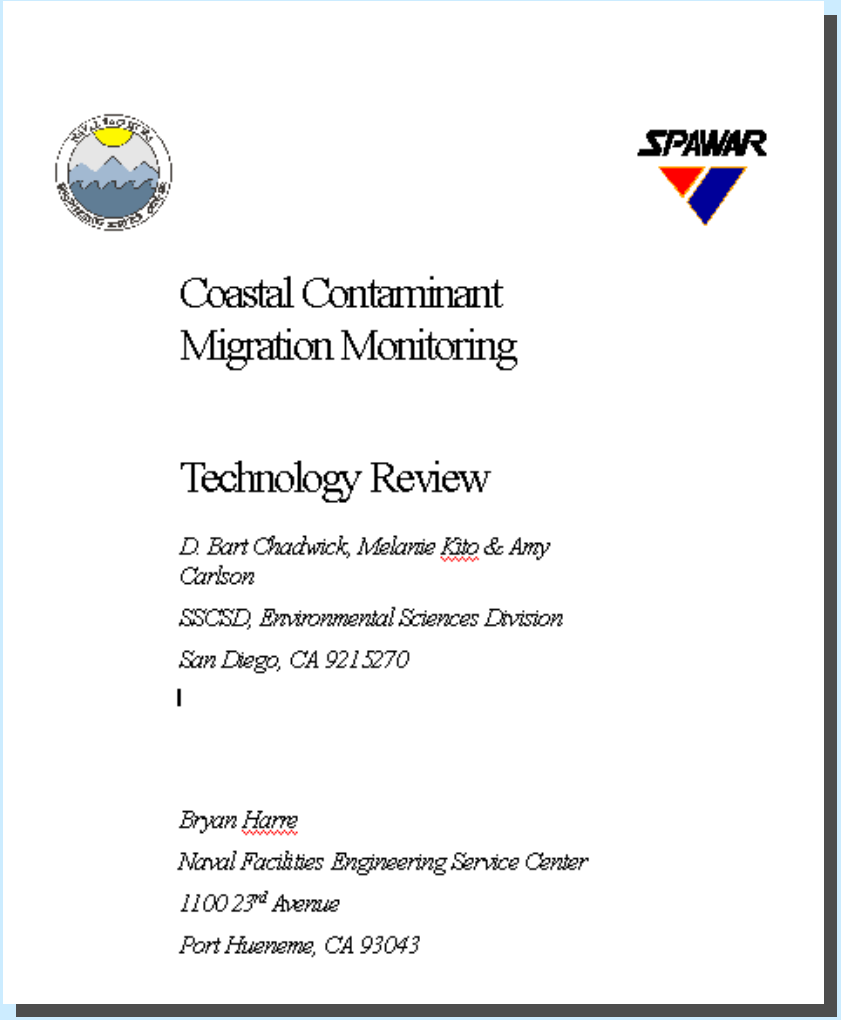
Existing Technologies

Technologies Reviewed

- Flow Detection
  - Seepage Meters
  - Thermal Gradient Flowmeters
  - Piezometers
  - Thermal Infrared Aerial Imagery
  - Tracer Injection
  - Colloidal Borescope
  - Natural Geochemical Tracers
- Contaminant Detection
  - Porewater probes
  - Seepage Meters
  - Flow Probe™ Chemical Analyzer
  - Diffusion Samplers



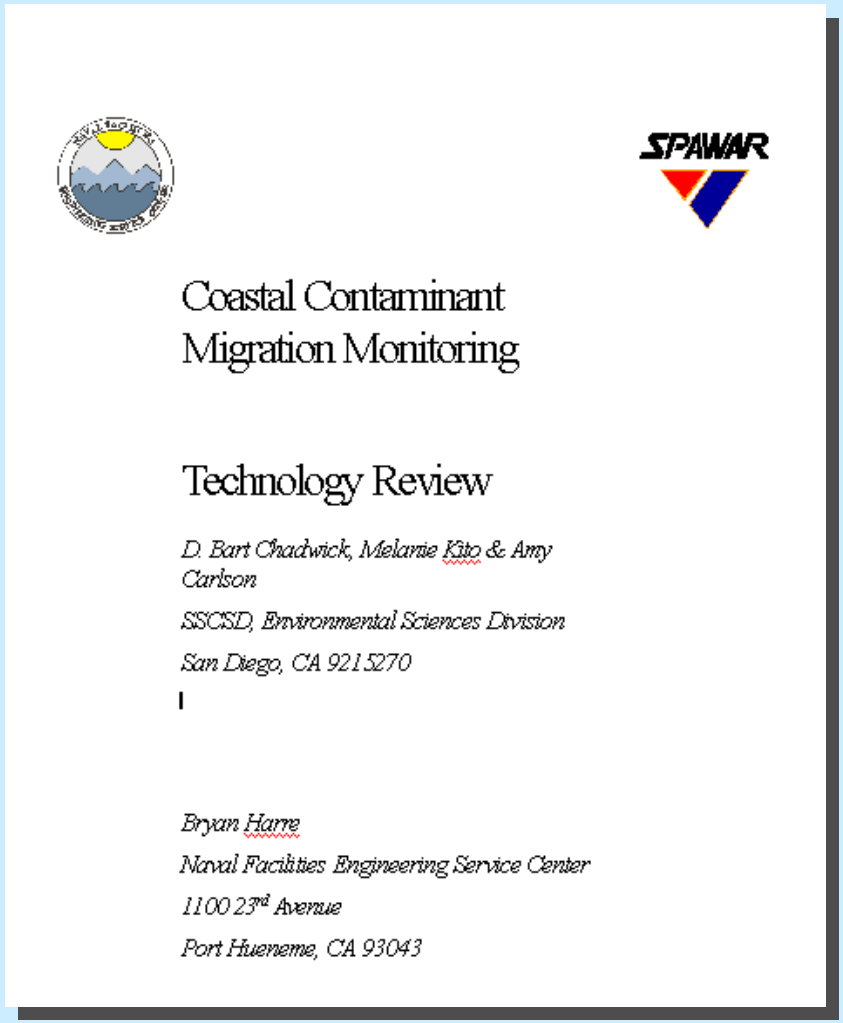
Technologies Evaluated

Technology Types Evaluated

- Flow Detection
- Contaminant Detection

Technologies Selected for Development and Demonstration

- Temperature/Conductivity/Pore-water Probe (Trident® Probe)
- Ultrasonic Multi-Sample Seepage Meter (UltraSeep Meter)
- Passive Diffusion Bag Sampler



SPAWAR

Coastal Contaminant Migration Monitoring

Technology Review

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Trident® Probe Development

- Development based on work at Cornell showing utility of conductivity for detecting regions of groundwater discharge
- Trident Probe refined to incorporate temperature detection and water sampling based on technology review and user input

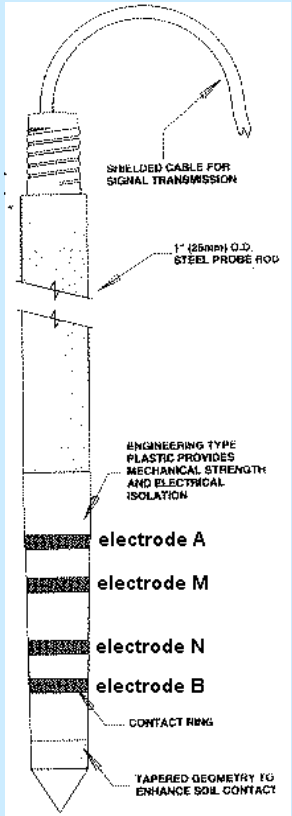
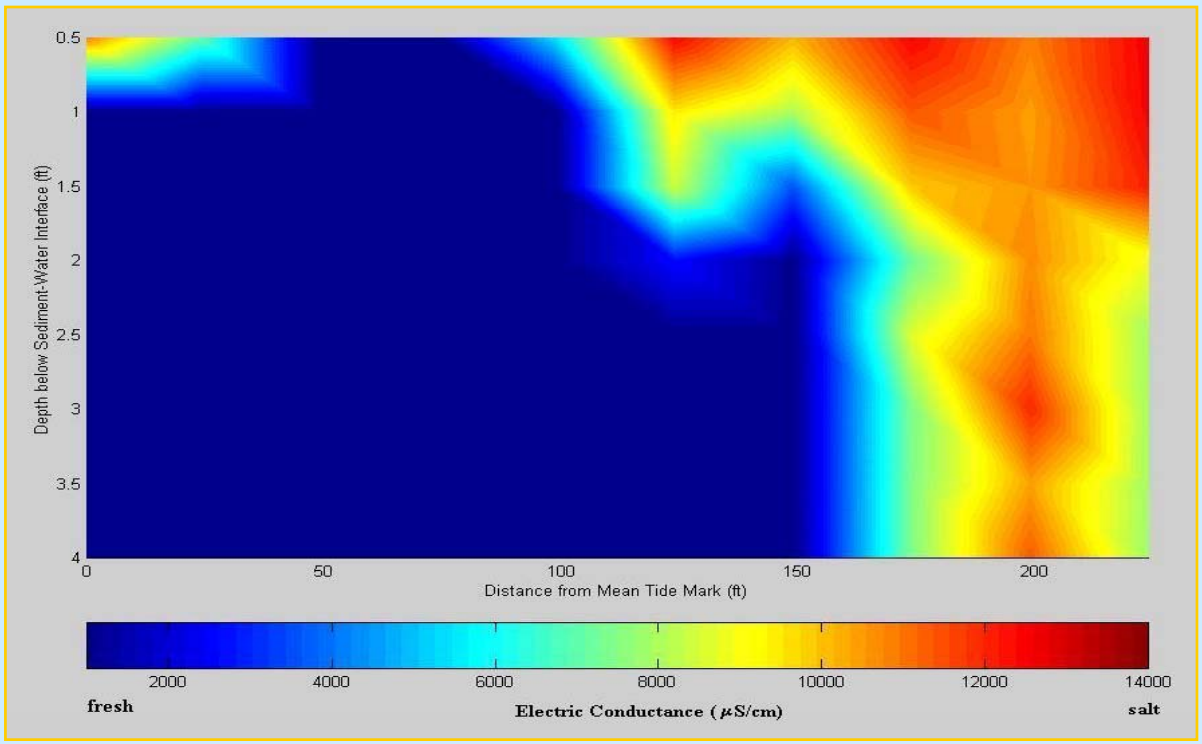
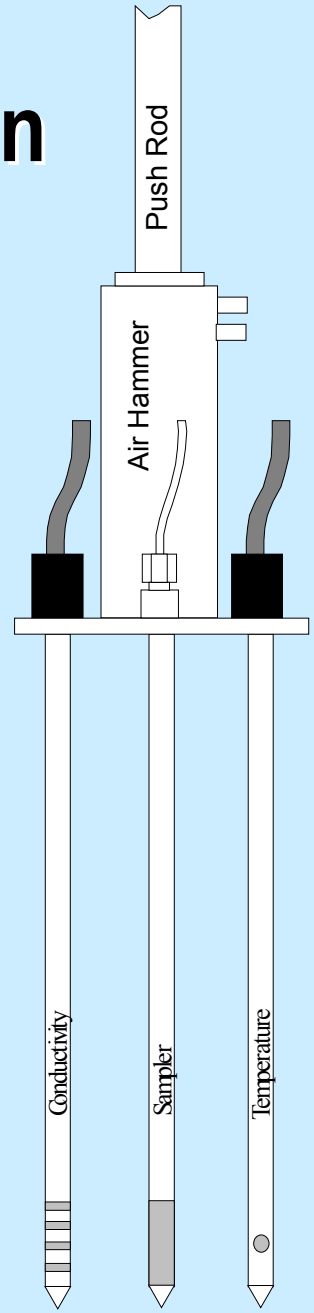


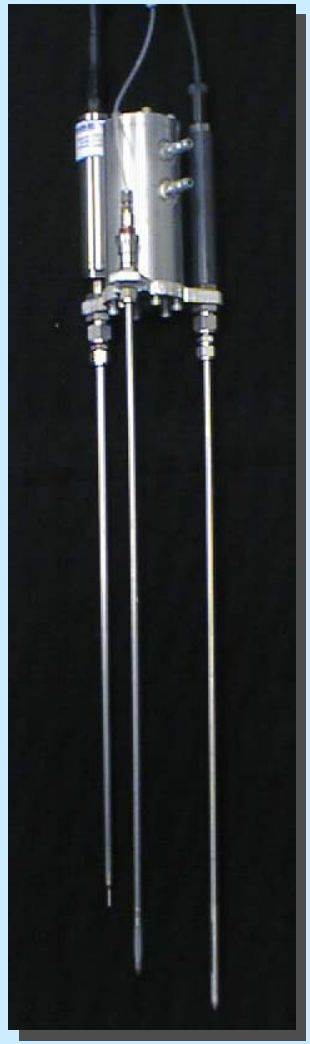
Figure 2.Configuration of the Wenner array.



Trident® Probe Description

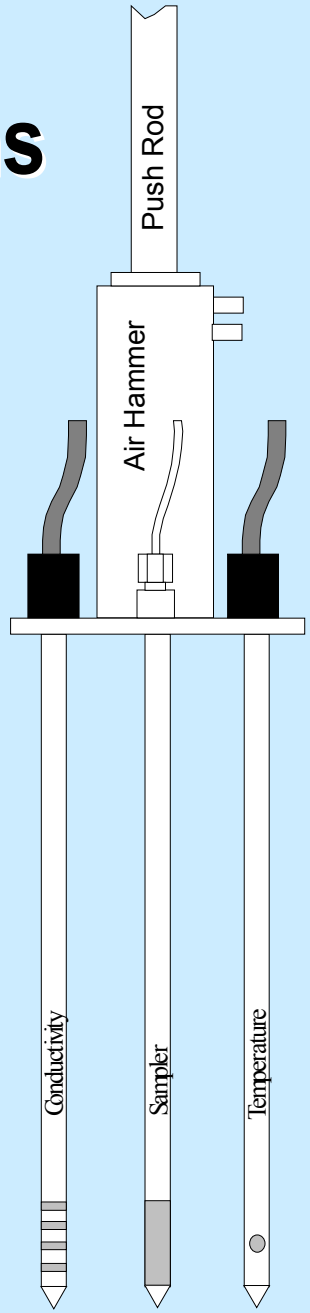
- A flexible, multi-sensor water sampling probe for screening and mapping groundwater plumes at the surface water interface
  - Conductivity – detects contrast in salinity and/or clay content in unconsolidated sediments
  - Temperature – detects groundwater by thermal contrast with surface water
  - Porewater Sampler – allows contaminant characterization and detection of other groundwater-specific tracers

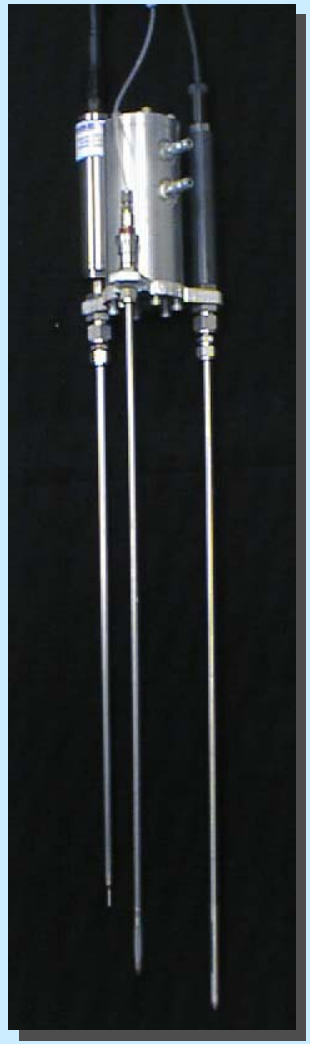




Trident® Probe Specifications

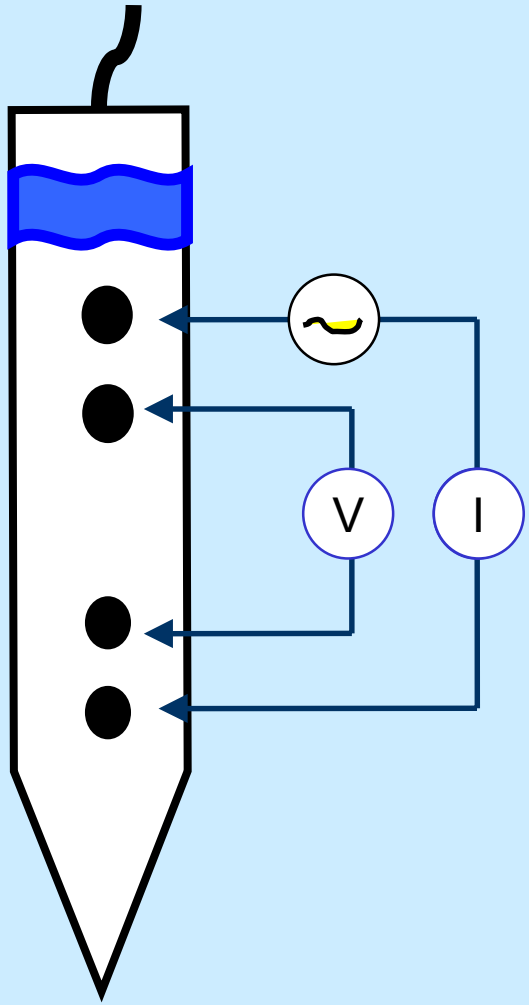
- Probe Length 24"
- Stainless Steel Construction
- Conductivity: 0-70 ± 1 mS/cm
- Temperature: –5-35 ± 0.001°C (10 s)
- Porewater: Vacuum collected with pore size ranging from ~1-240 µm
- Air Hammer: Allows easy insertion into a variety of sediment types





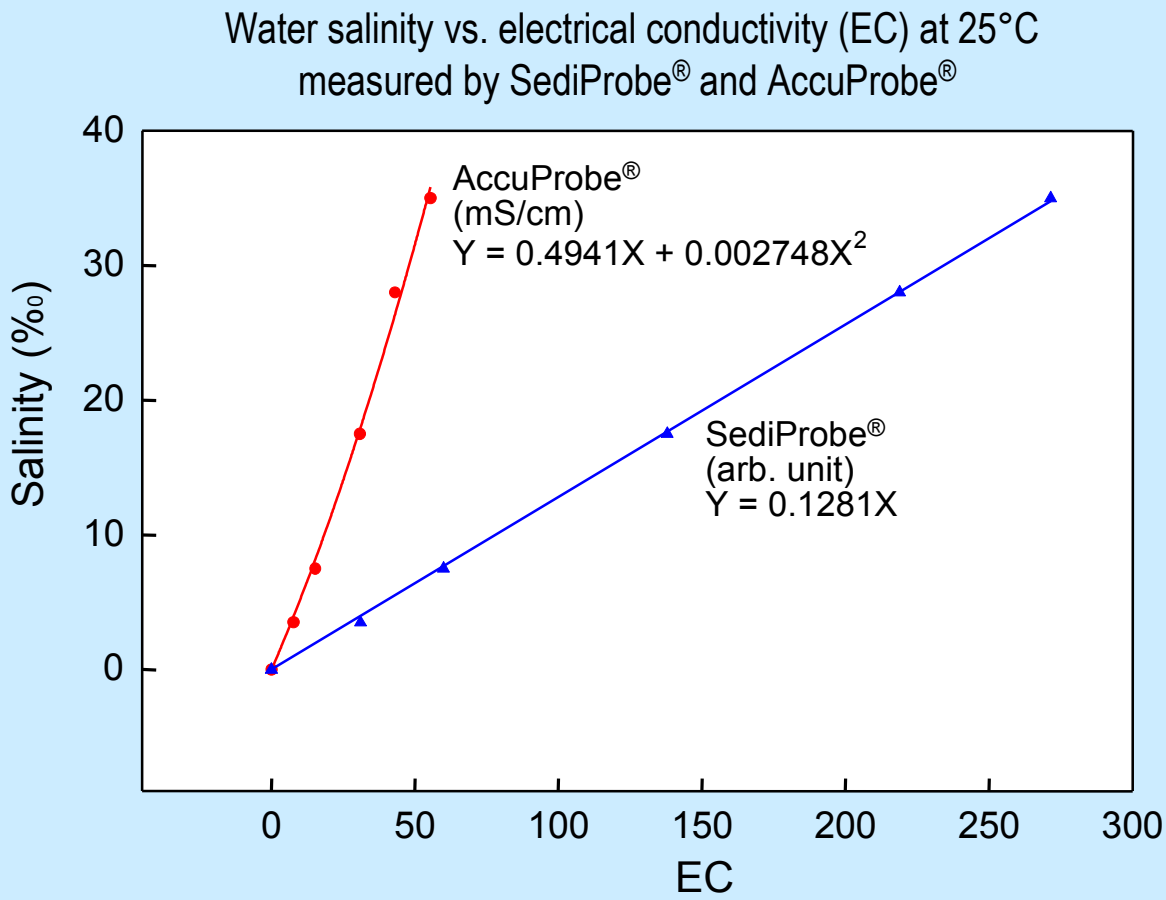
Trident® Conductivity Probe Configuration

- Custom-built submersible four-electrode probe
- Utilize "Wenner" or dipole modes to measure resistance across electrodes
- Developed in consultation with Geoprobe®
- Compatible with standard Geoprobe® deck unit and software



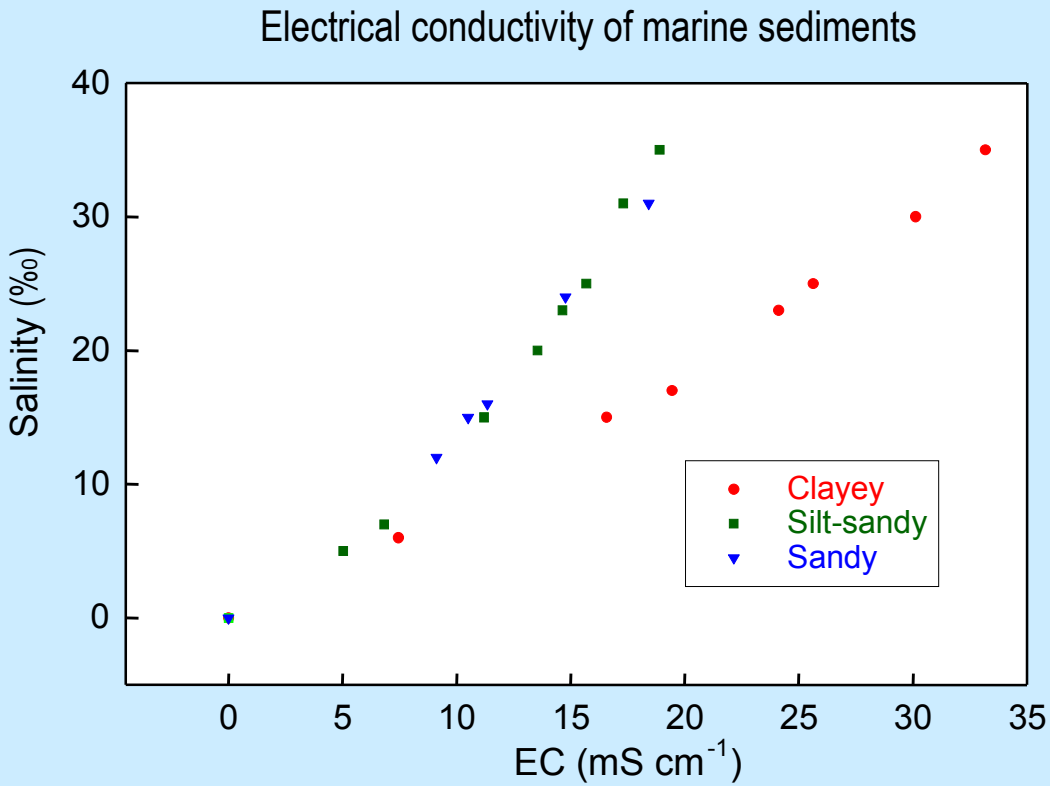
Trident® Conductivity Probe Calibration Test

- Calibrated in solution over broad range of salinity
- Calibration curve developed against standard laboratory AccuProbe® system
- Final values corrected to standard temperature (25°C)



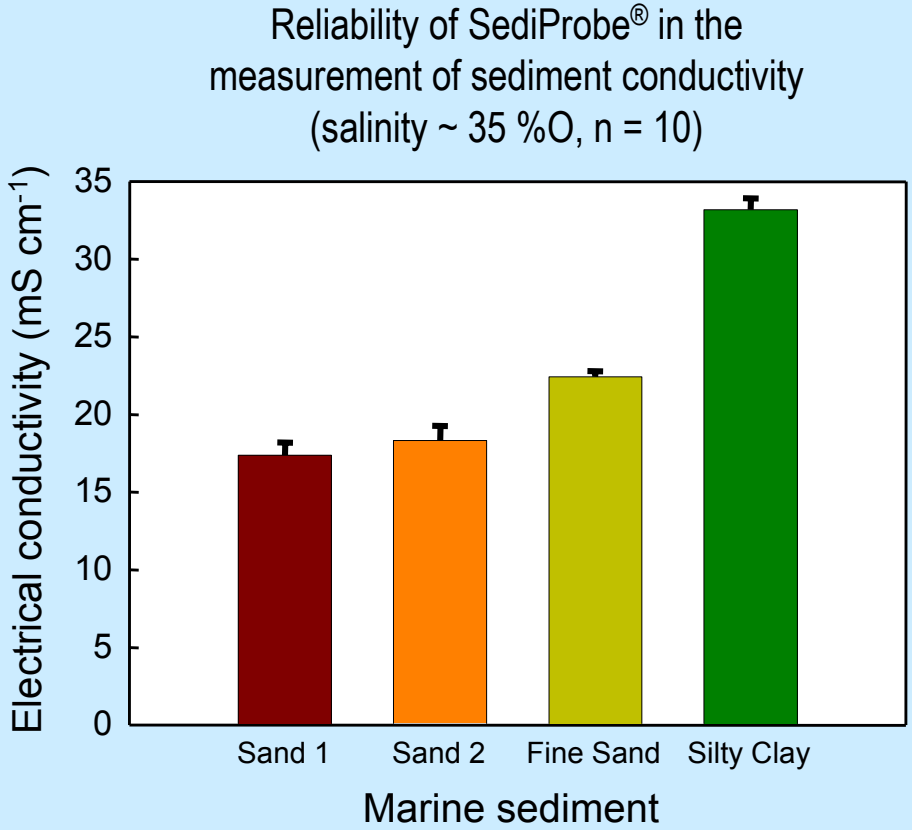
Trident® Conductivity Probe Calibration Test (cont.)

- Testing conducted in a range of sediment types
- Probe response found to be stable and repeatable
- Conductivity of clayey sediments is enhanced by surface conductance of the clay particles
- Important characteristic is that low salinity and low clay both manifest as low conductivity



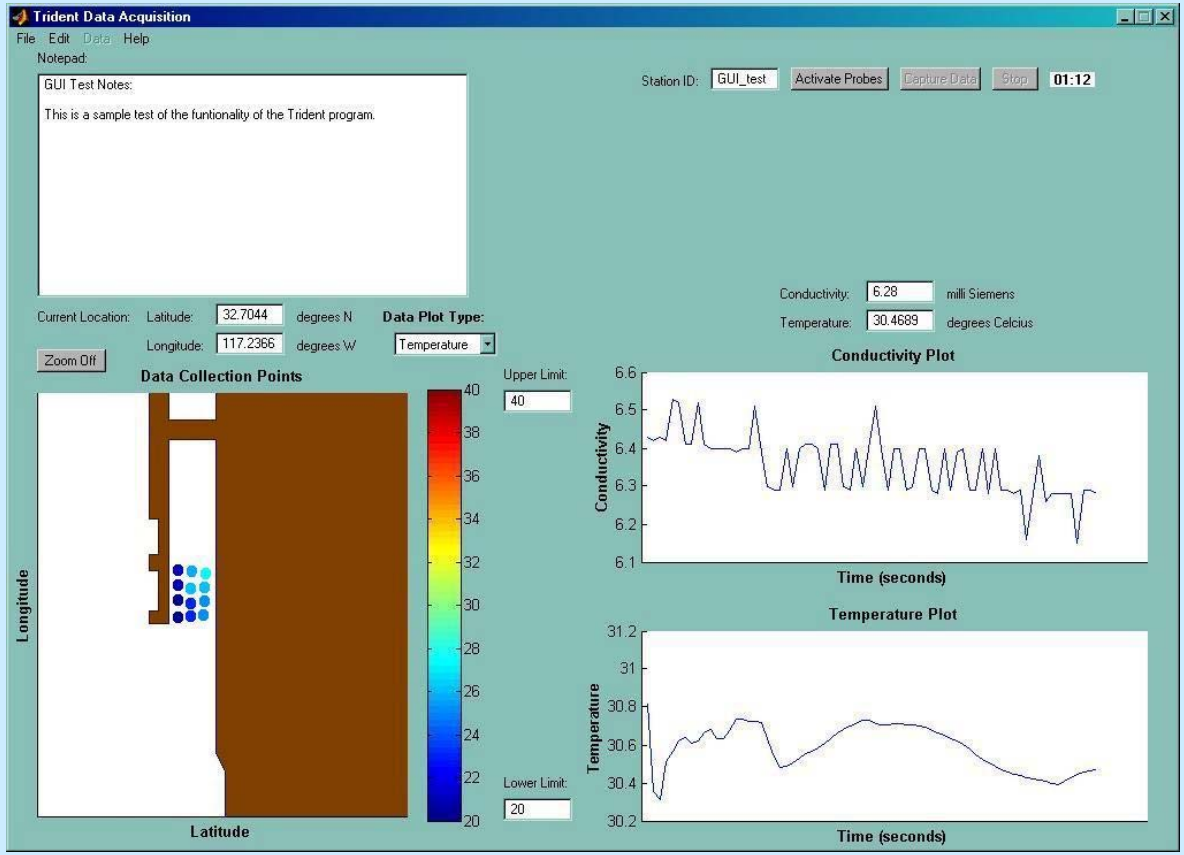
Trident® Laboratory Sediment Testing

- Conductivity probe evaluated for repeatability over range of sediments
- Probe response found to be stable and repeatable
- Demonstrated detectable differences between various sediment types and salinity concentrations in laboratory samples



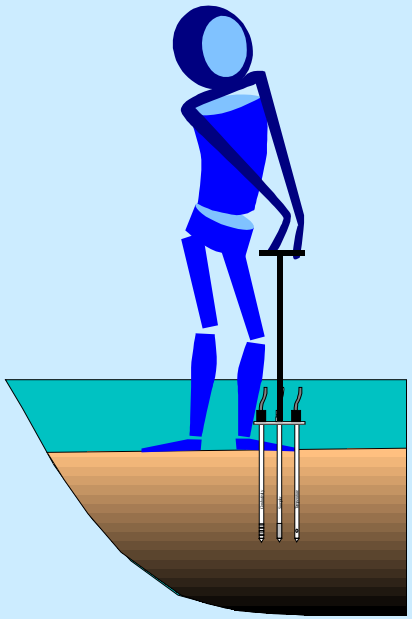
Trident® User Interface

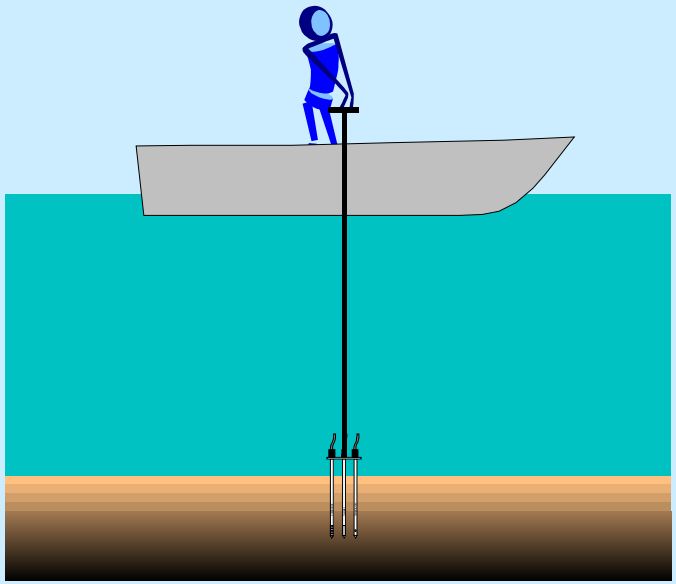
- Integrates GPS, temperature and conductivity signals
- Provides real-time display of spatial distribution
- Allows input of auxilliary water quality measurements

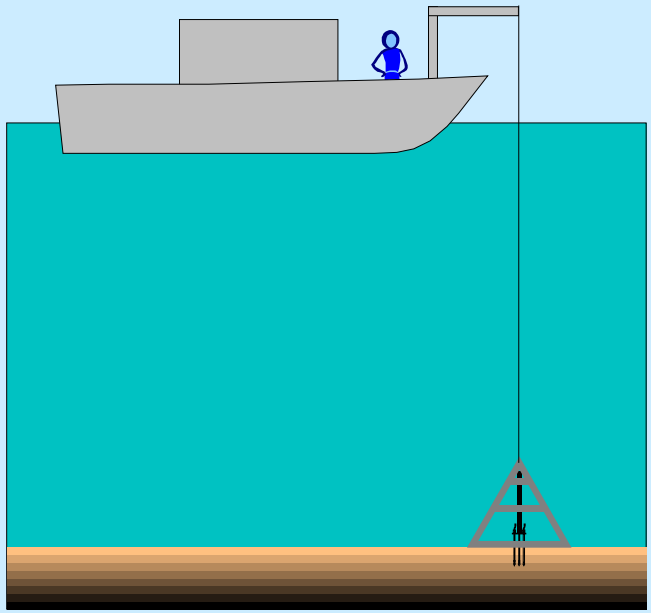


Trident® Field Deployment

- Very Shallow (0'-3')
  - Manual deployment from shore
- Shallow (2'-30')
  - Manual deployment from small boat
- Deep (30'-60')
  - Remote deployment with bottom lander or by diver







Trident® Probe Field Test Summary

- Trident Probe field testing conducted successfully for a range of different sites and deployment strategies

Test Site	Capability Tested	Deployment Mode
North Island Site 9	Porewater	Shallow Deep
Anacostia River	Porewater Conductivity	Very Shallow Shallow
Eagle Harbor	Porewater Conductivity	Very Shallow Shallow Deep
Kellogg's Beach	Porewater Conductivity Temperature	Very Shallow
SSC-SD Pier 159	Conductivity Temperature	Shallow
Naval Station San Diego	Conductivity	Deep (Diver)
North Island Site 9	Porewater Conductivity Temperature	Shallow
Pearl Harbor	Conductivity	Deep (Diver)

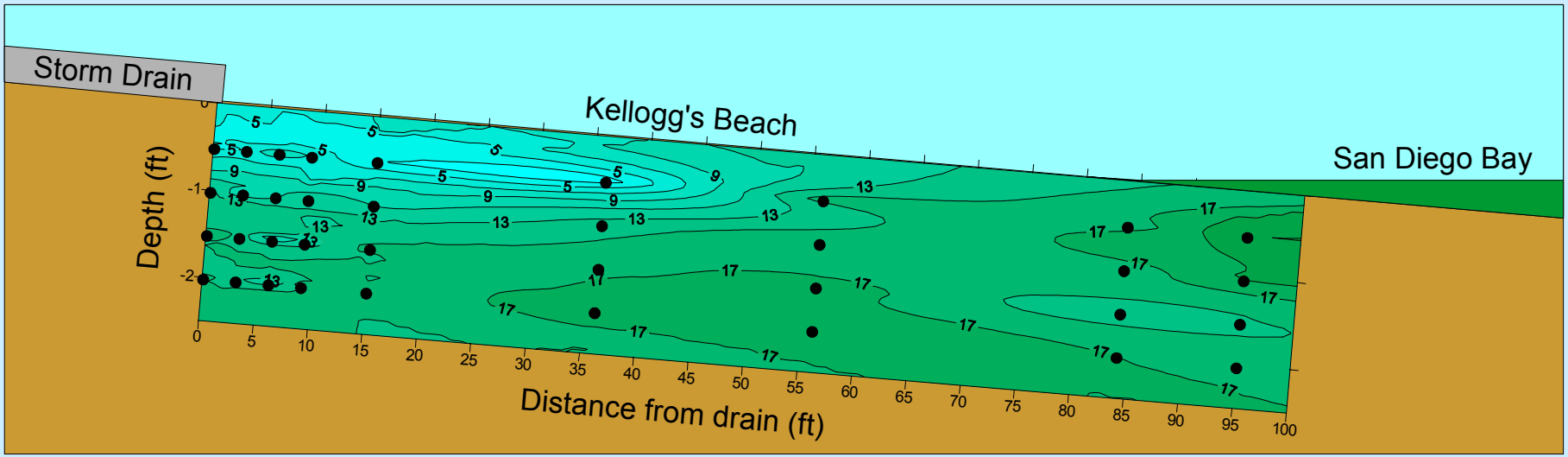
Trident® Probe Field Test
Kellogg's Beach

- Initial test at Kellogg's Beach storm drain site
- Test in very shallow water mode

- Profiled conductivity and temperature at ~6" depth intervals along a 100' transect
- Collected porewater confirmation samples for salinity

Trident® Probe Field Test
Kellogg's Beach (cont.)

- Successfully deployed and profiled system on site
- Mapped conductivity, clearly delineated freshwater plume
- Entire transect completed in about 2 hours including collection of water samples



Trident® Probe Field Test
North Island Site 9

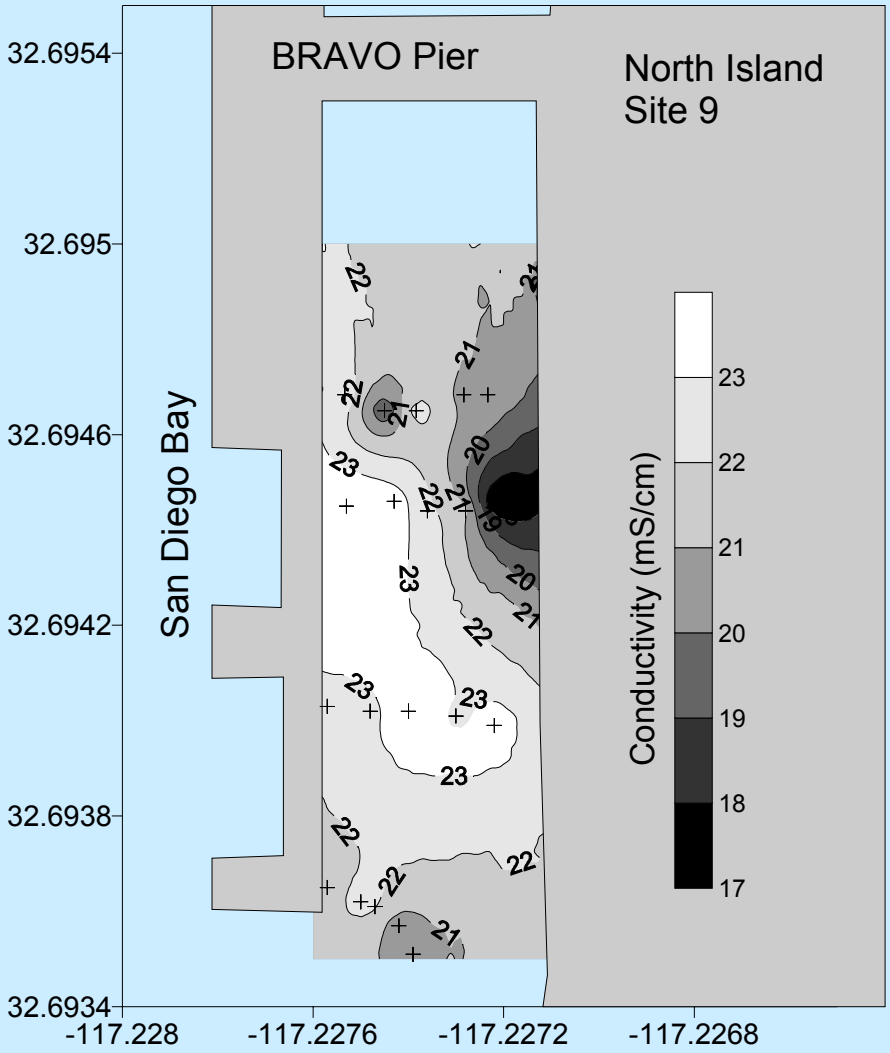
- Full-scale test at North Island Site 9
- Test in shallow water mode
- Evaluated mooring and push protocols

- Mapped conductivity and temperature at ~2' depth across ~100m X 200m area
- Collected porewater samples at all stations for salinity

Trident® Probe – Conductivity Mapping

North Island Site 9 (cont.)

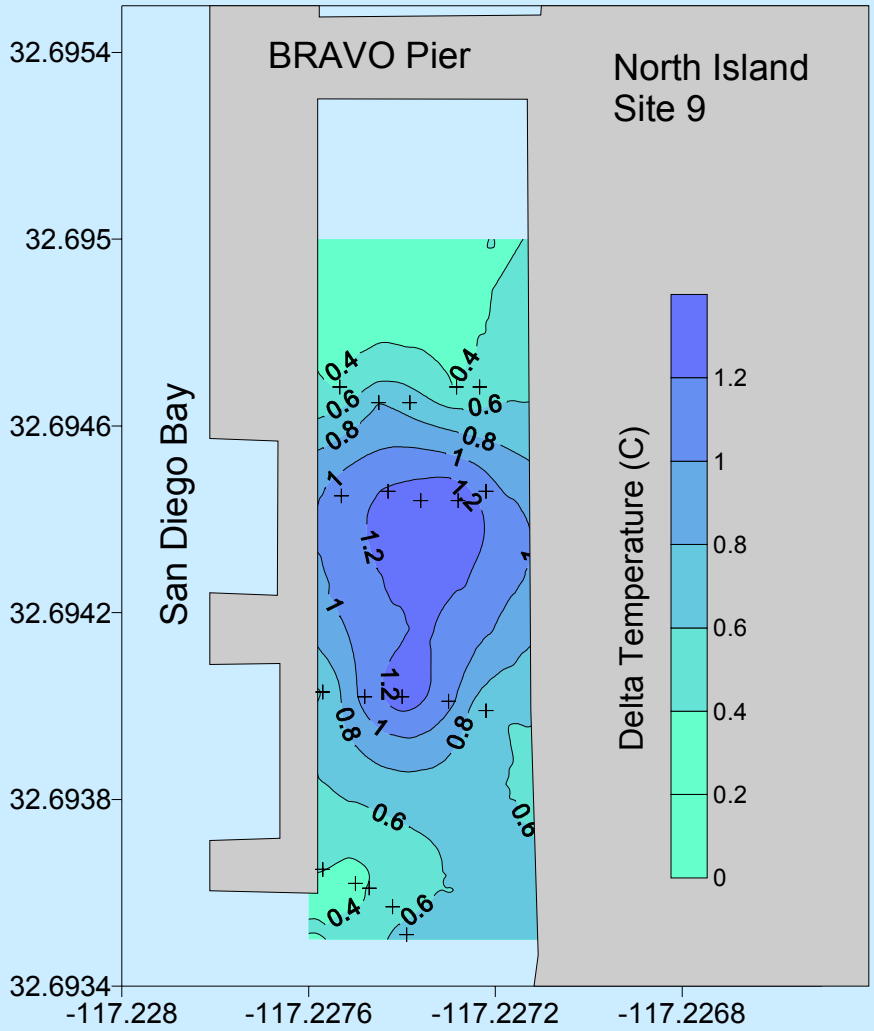
- Trident probe used to map out conductivity in subsurface (2') porewaters
- Conductivity indicates relatively permeable sandy sediments throughout the site
- No clear pattern in relation to contamination



Trident® Probe – Temperature Mapping

North Island Site 9 (cont.)

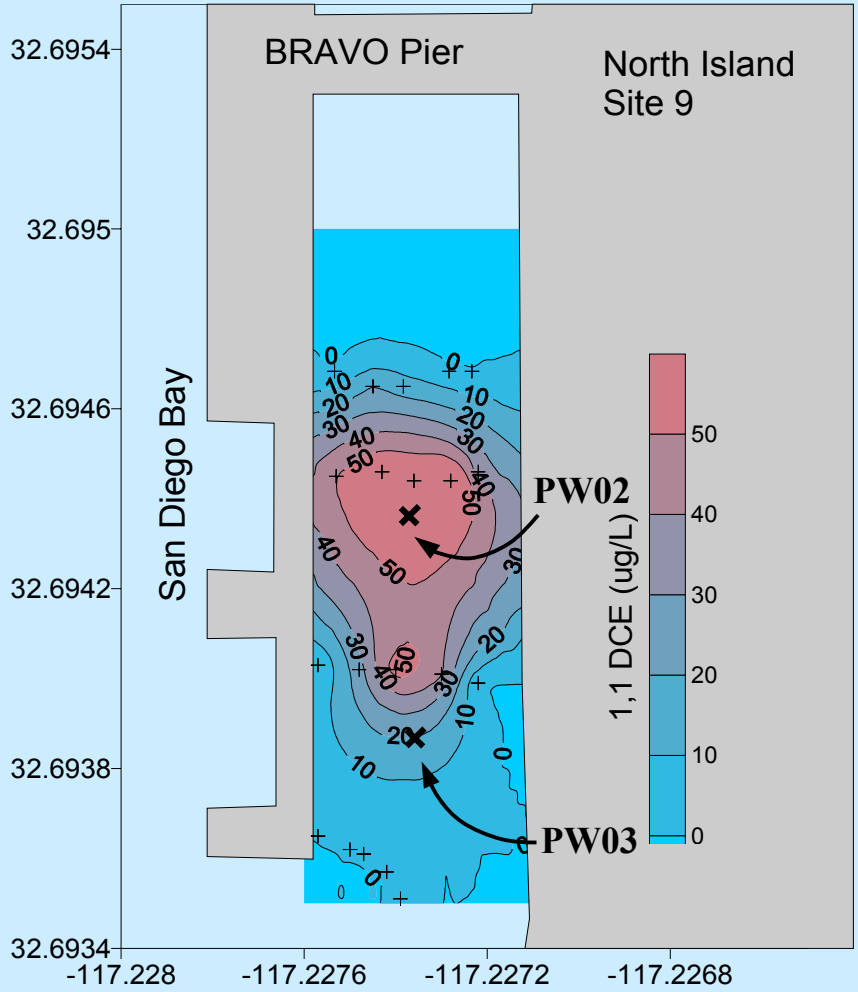
- Trident probe used to map out temperature contrast between surface water and subsurface (2') porewaters
- Temperature contrast mapping indicated area where cooler groundwater could be entering the bay
- Strong correspondence with VOC distribution



Trident® Porewater Sampler – DCE Mapping

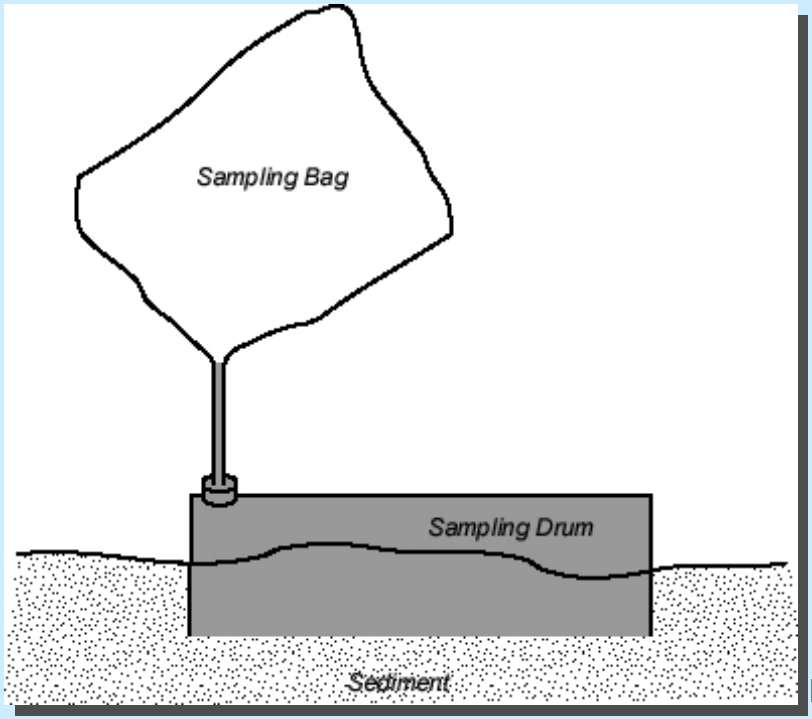
North Island Site 9 (cont.)

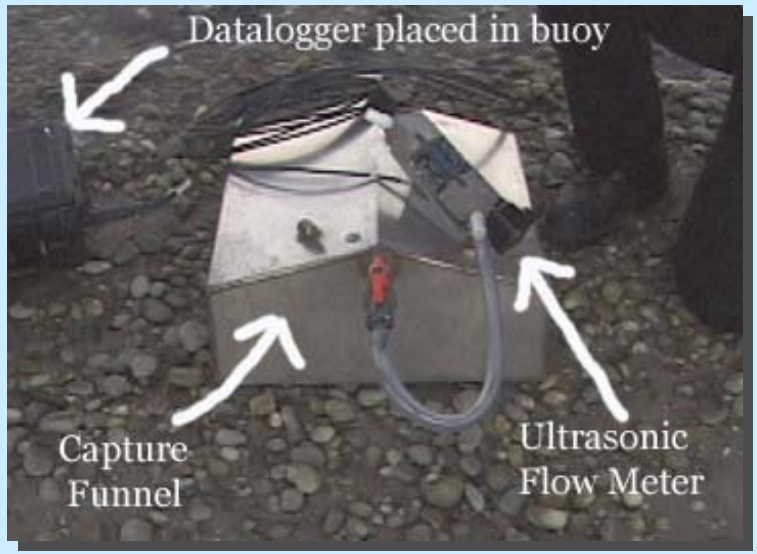
- Trident porewater probe used to collect subsurface (2') samples at 20 stations
- Porewater samples were analyzed for target VOC compounds
- Mapping isolated area where VOCs seep into the bay



UltraSeep® Development

- UltraSeep evolved from earlier prototype seepage meters
- Development of flow and sampling system in conjunction with Cornell





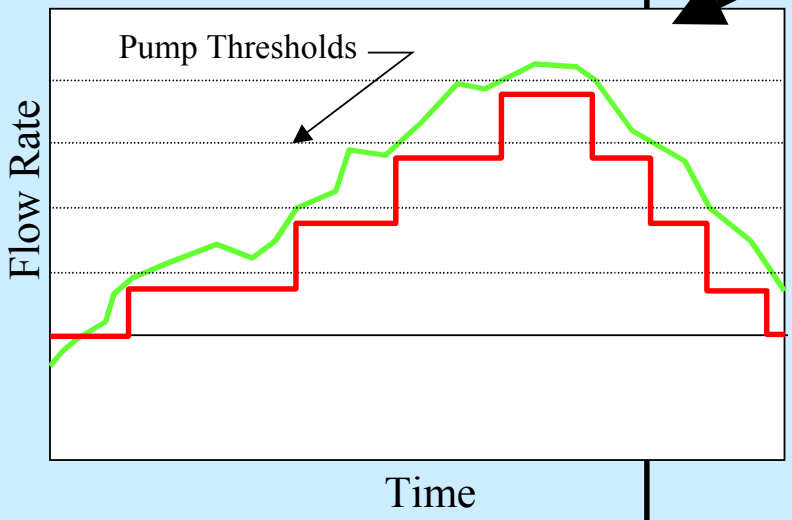
UltraSeep® Description

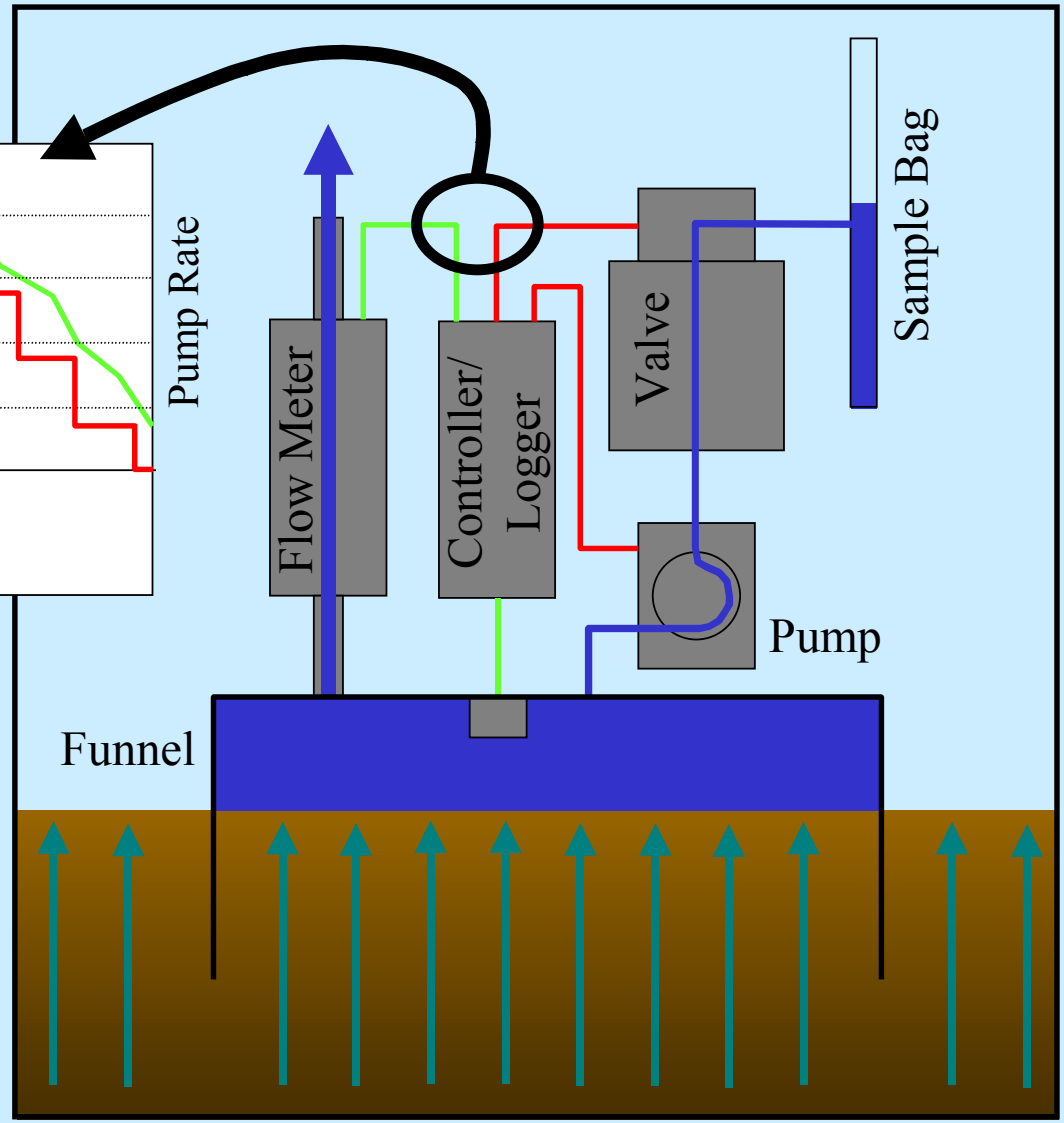
- A modular, state-of-the-art seepage meter for direct measurement of groundwater and contaminant discharges at the surface water interface
  - Ultrasonic flowmeter – provides direct measurement of groundwater flow
  - Water sampler – Low-flow peristaltic pump with sample selector valve and sample-bag array
  - On-board sensors/controller – Temperature and conductivity on-board, controller stores data and controls sampling events

Sample Bag


Battery
ESM Controller
Logger
Water Sampler
Flow Meter
Funnel

UltraSeep® Functional Schematic

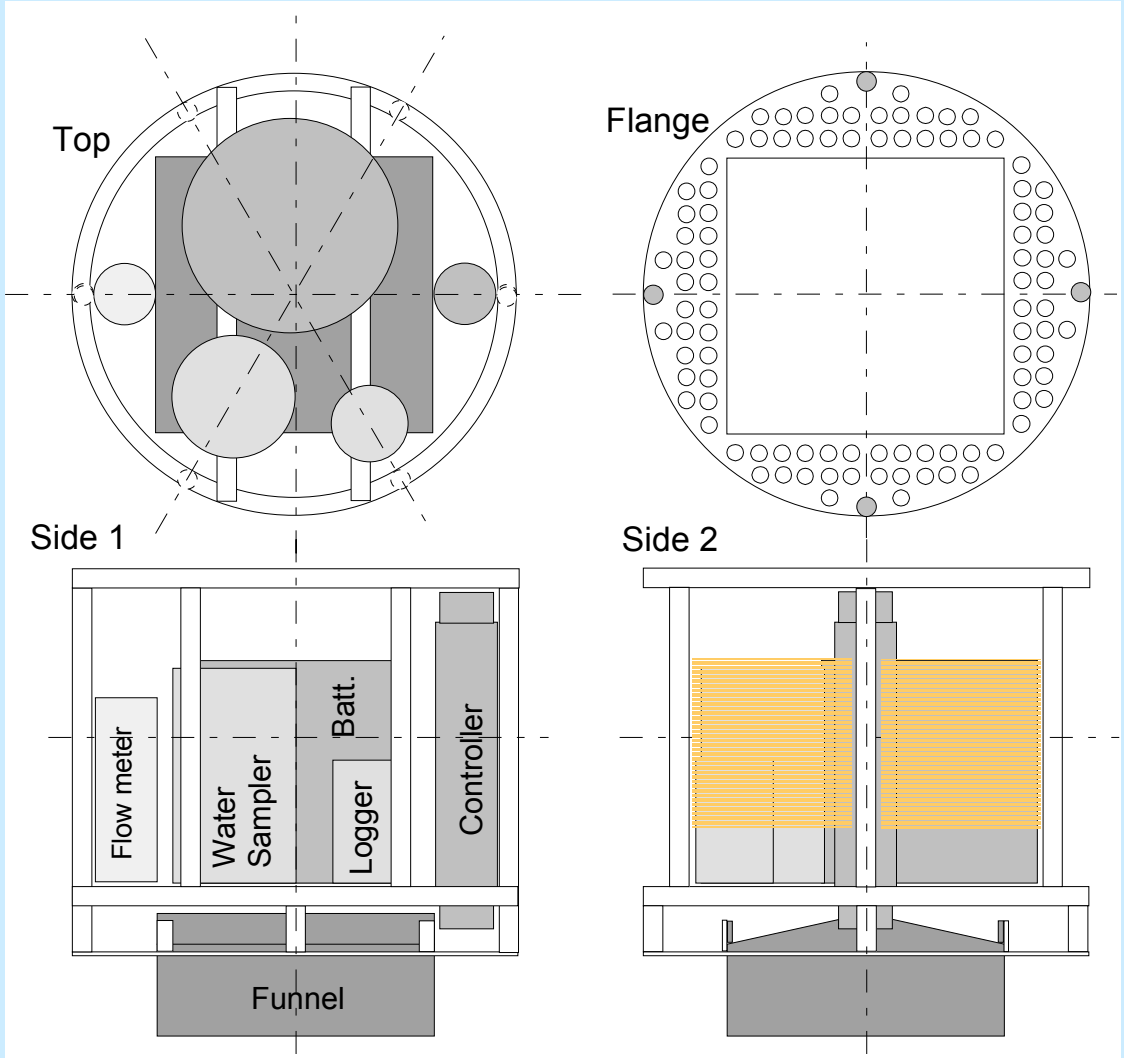




- Feedback control system regulates water sampling
- Maximizes sampling volume without restricting flow

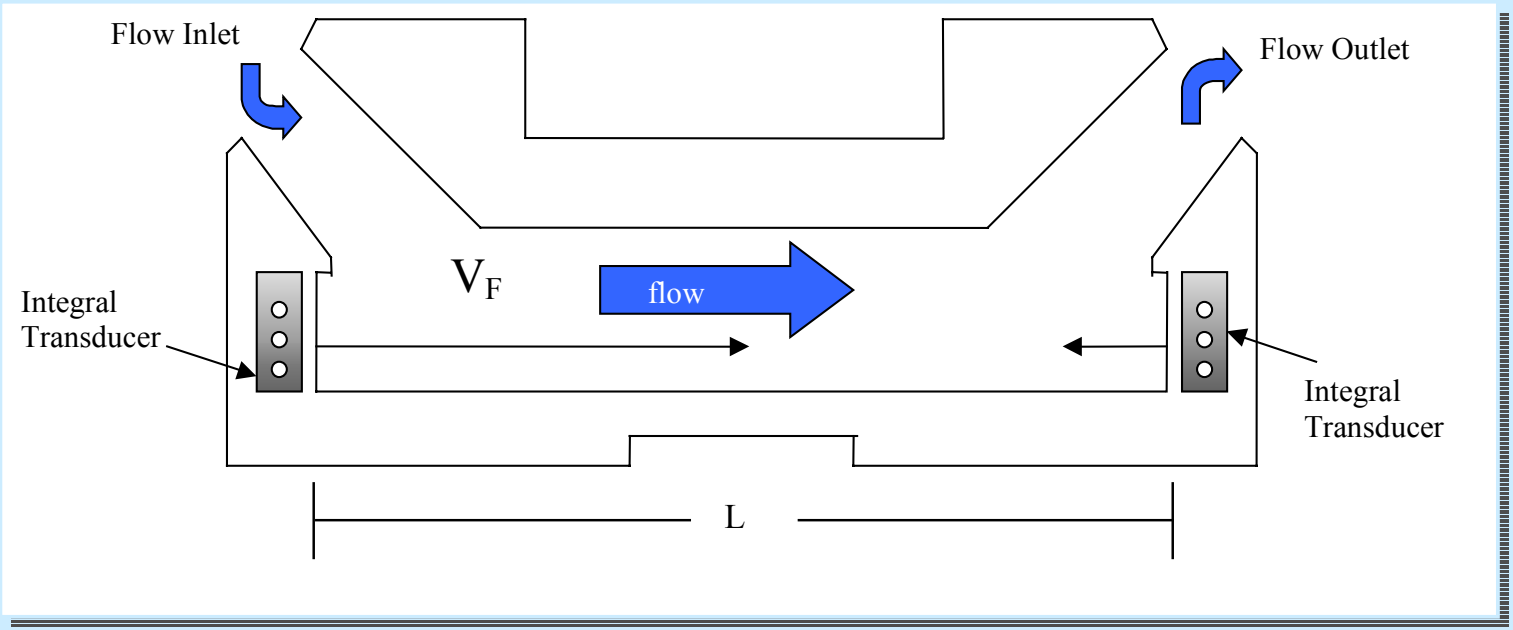
UltraSeep® Specifications

- Ultrasonic flowmeter: Accurate detection of specific discharge or recharge in the range of 0.1 - 150 cm/d
- Water Sampler: Programmable collection by time or flow condition at 0.2-20 mL/min via 6-port selector valve into pre-cleaned teflon bags
- Conductivity: 0-7 ± 0.001 mS/cm
- Temperature: -5-35° ± 0.001° C
- Controller: 8/12-Channel I/O, 128 MB memory, RS-232 and 1-2 amp power switching



UltraSeep® Flowmeter
Theory of Operation

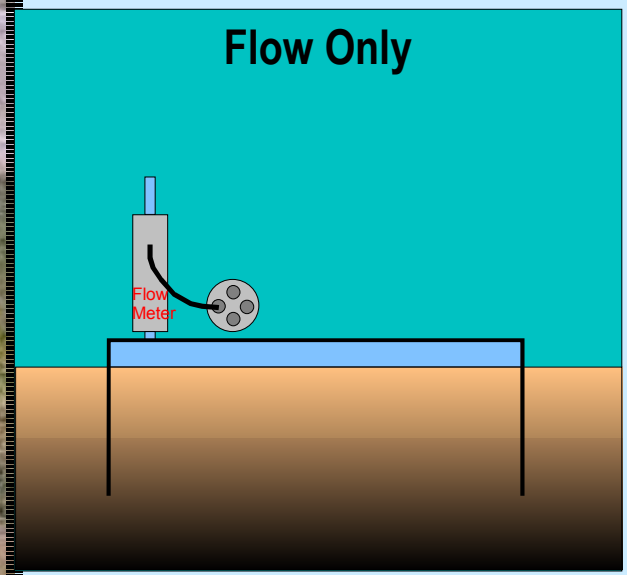
- Utilizes off-the-shelf Controlotron® ultrasonic flowmeter
- Flow measurement based on difference in travel time of ultrasonic pulses along flow path
- Meter testing and calibration conducted in Cornell laboratory test facility

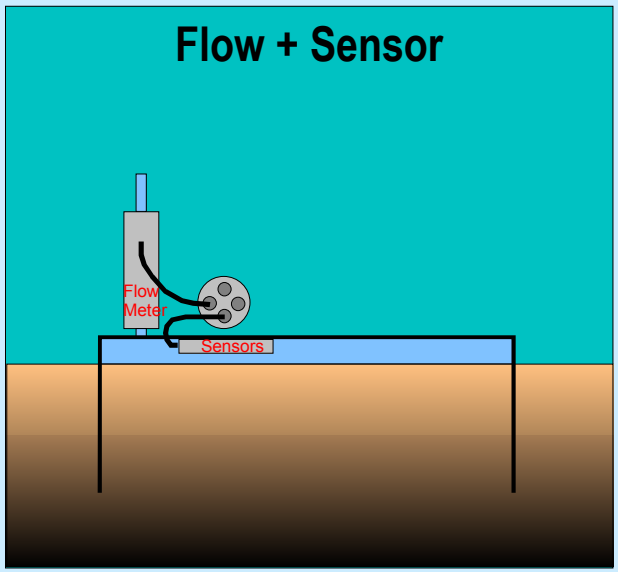


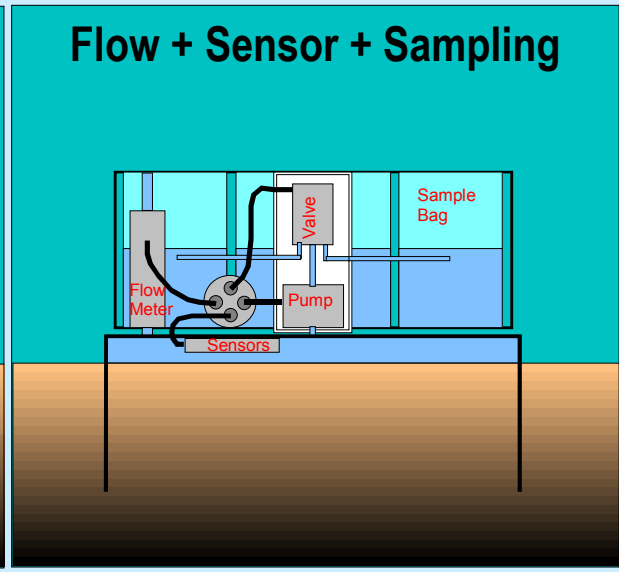
UltraSeep®
Flexible Deployment

Configurations

- Flow Only: To determine rate of discharge/recharge
- Flow and Sensors: Incorporates groundwater indicators
- Flow, Sensors, and Sampling: Allows complete quantification of flow and contaminant levels







UltraSeep®
Field Testing Summary

- UltraSeep field testing conducted successfully for a range of different sites and field conditions

Test Site	Capability Tested	Deployment Mode
North Island Site 9	Bag Sampler	Diver
Anacostia River	Ultrasonic Meter Bag Sampler (independently)	Diver
Eagle Harbor	Ultrasonic Meter Bag Sampler (independently)	Diver
Naval Station San Diego	Ultrasonic Meter w/sensors	Diver
North Island Site 9	Integrated Meter	Diver
Pearl Harbor	Integrated Meter	Diver

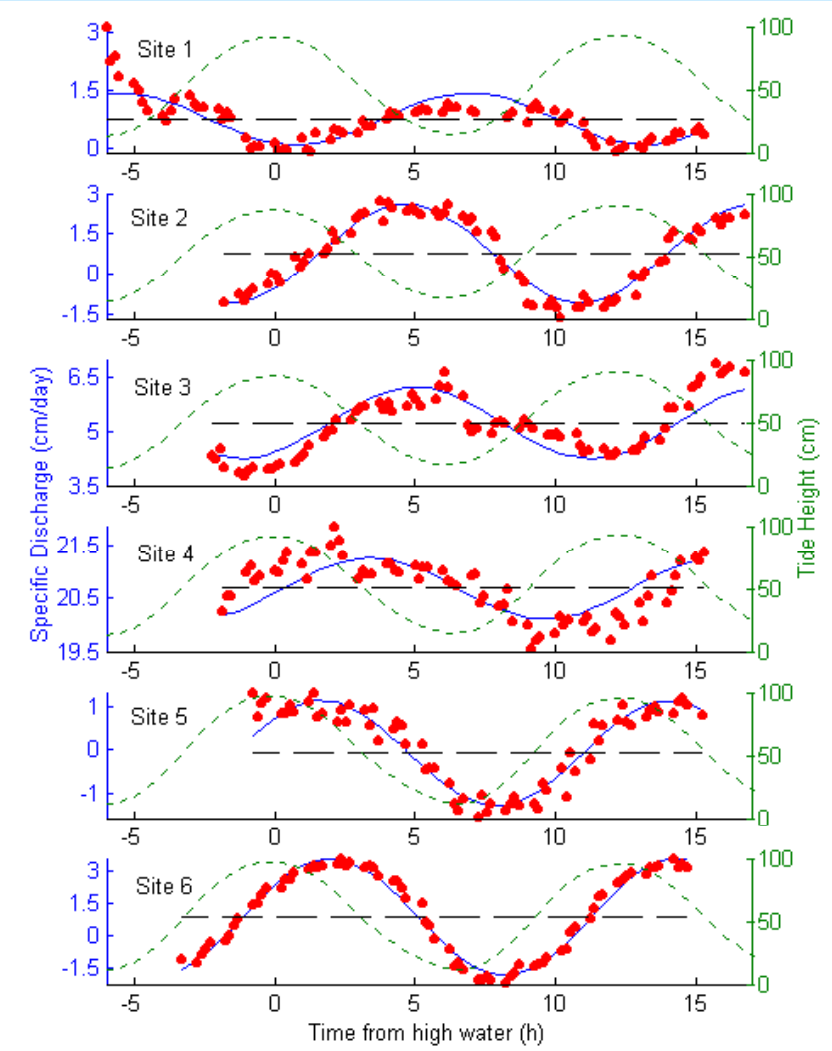
UltraSeep®
Anacostia River Field Test

- Six stations sampled in Anacostia River
- Measured in flow/sensor mode in shallow water

- Independently tested water sampling system
- All deployments by diver

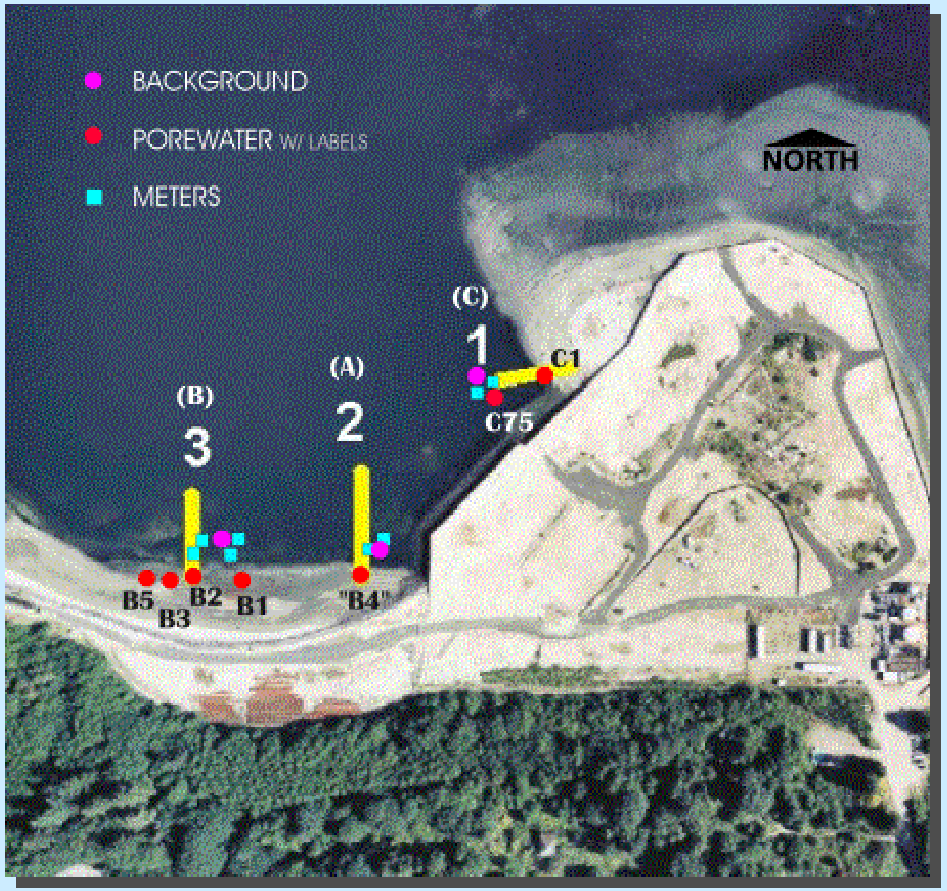
UltraSeep®
Anacostia River Field Test (cont.)

- Successfully resolved low-level tidally driven seepage at all sites
- Ultrasonic meter provides significant improvement in flow detection over "bag" type samplers
- Water sampling system tested successfully at all stations but requires integration with flowmeter to improve control over sample volumes



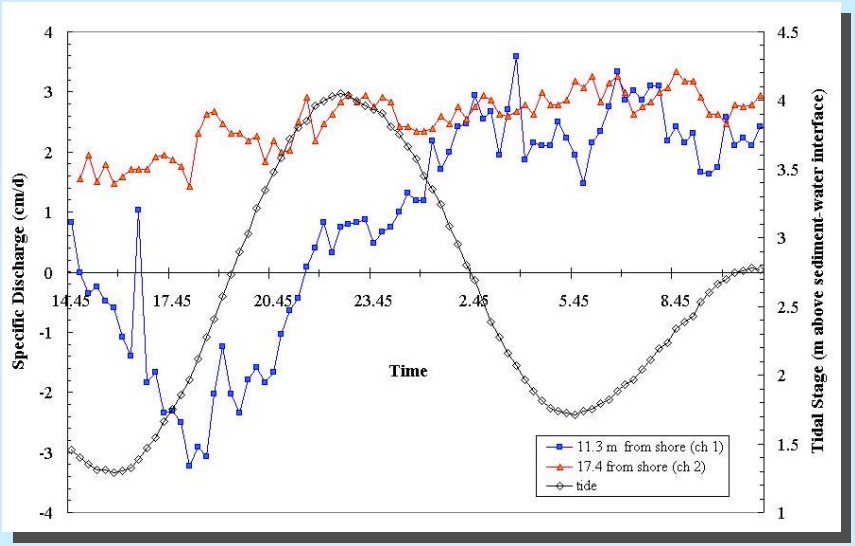
UltraSeep®
Eagle Harbor Field Test

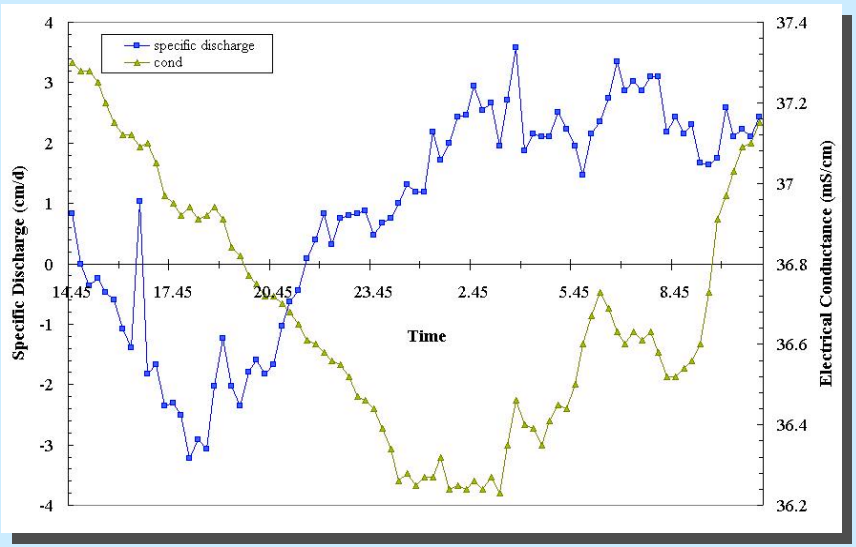
- EPA Superfund site
- Sample 8 stations on 3 transects off Wycoff Facility (deep water)
- Measured in flow/sensor mode



UltraSeep®
Eagle Harbor Field Test (cont.)

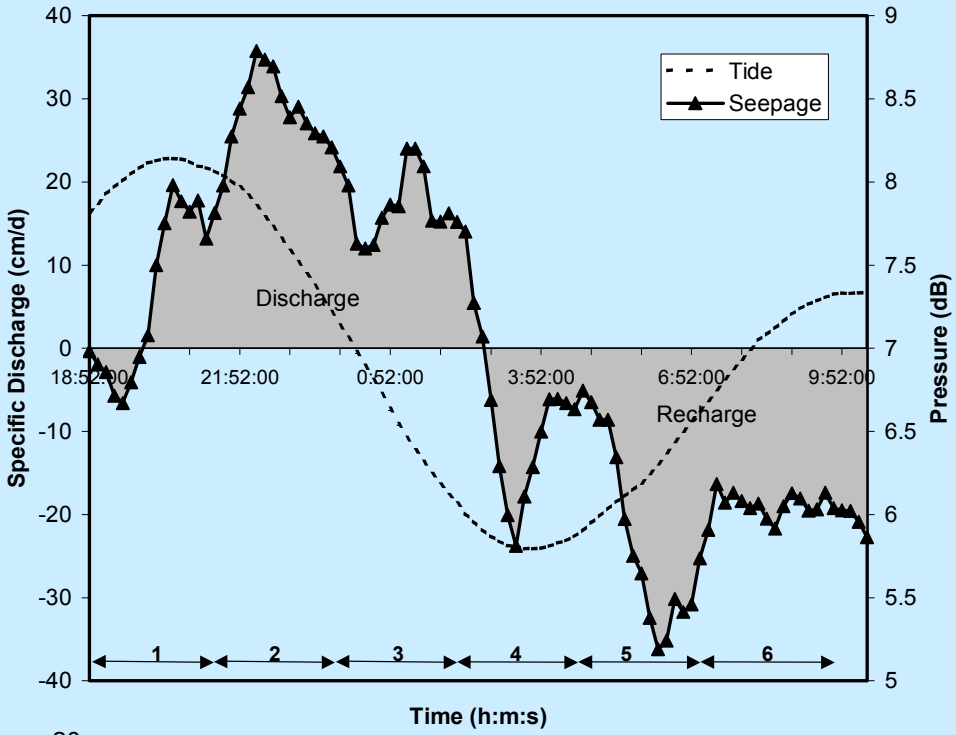
- Successfully measured groundwater exchange rates at all 8 stations
- Detected non-tidal and tidal flow signals at rates from –5 to 5 cm/day
- On-board conductivity sensor provides additional evidence of freshwater discharge during and after low tide

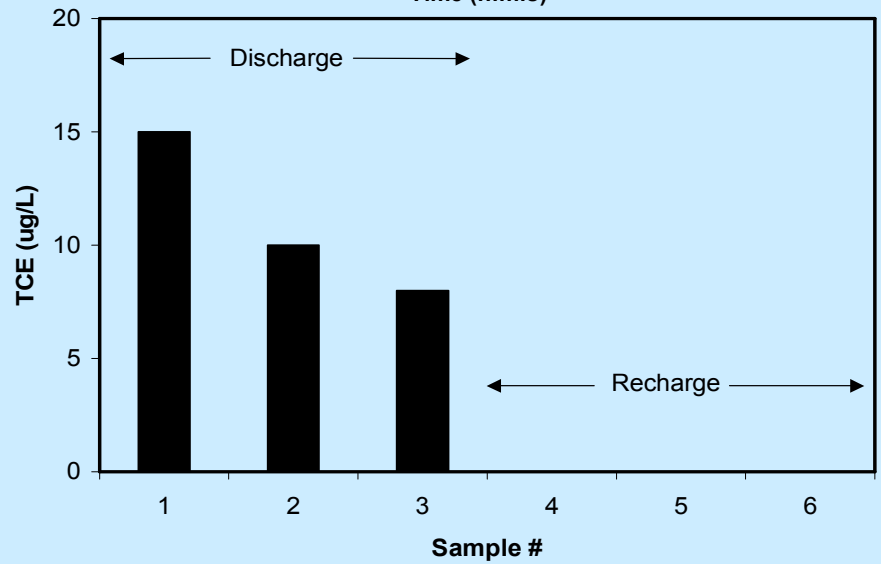




UltraSeep®
North Island Site 9 Field Test

- UltraSeep deployed in areas where the Trident Probe indicated potential groundwater seepage
- UltraSeep meter shows tidal variation in seepage rates
- TCE and other VOCs detected in UltraSeep samples during discharge periods





Technologies Summary and Conclusions

- Successfully developed and demonstrated Trident® probe for conductivity, temperature, and porewater collections under a variety of conditions
- Final demonstrations will focus on capability to collect and analyze chemical samples of adequate quality and volume
- Parallel testing of passive diffusion bag (PDB) samplers will extend capability to areas where porewater samplers are not effective
- Successfully demonstrated ultrasonic seepage meters as stand-alone flow devices and with integrated sensors for temperature and conductivity at a range of sites
- Final development and demonstration will focus on integration of water sampling capability for chemical analysis

Presentation Overview

- Background
- Technologies
- Information Resources
- Summary and Conclusions

Information Resources

- Report on the available monitoring and assessment technologies for coastal landfills and waste sites
- Demonstration report on tools for assessment of coastal contaminant migration
- Standard protocol for monitoring coastal sites including descriptions of monitoring technologies, sampling procedures, analytical procedures, reliability of results, and level of regulatory acceptance
- New commercialized instruments for assessment of seepage flow and contaminant migration

Information Resources (cont.)

- Regulatory Review:
  - U.S. EPA, CALEPA, state and local regulators at demonstration sites
- Technical Collaboration:
  - Cornell University, USGS, Ocean Science Group, U.S. EPA
- User POCs:
  - Bill Collins NAS North Island (619) 556-9901
  - Ed Dias EFD Southwest (619) 556-7318

Presentation Overview

- Background
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New Technology Issues

- Regulatory
  - Involve regulators up front
  - Integrate technology into site assessment plans
- Implementation
  - Training/education of RPMs on technology
  - Industry partners for commercialization and application
- Public Perception
  - Attend regulatory/Restoration Advisory Board (RAB) meetings to discuss technology
  - Establish track record based on demonstrations and application at cleanup sites

References

- Documents
  - Technology Survey Report
  - Technology Selection Report
  - Protocols for Groundwater/Surface Water Measurements
  - Technology Demonstration Report
- Web Sites
  - http://www.nfesc.navy.mil
  - http://environ.spawar.navy.mil/

Summary

- Cleanup of sites with landfills/plumes located adjacent to harbors, bays, estuaries, wetlands, and other coastal environments
- New technologies have been developed to improve our ability to assess flow and contaminant detection
  - Temperature/Conductivity/Porewater Probe (Trident® Probe)
  - Ultrasonic Multi-Sample Seepage Meter (UltraSeep® Meter)
- Access to technology will be implemented through partnership with SPAWAR/NFESC/users and commercialization

Navy Points of Contact

- NFESC
  - (805) 982-1795
  - http://www.nfesc.navy.mil
- SPAWAR
  - (619) 553-5333
  - http://environ.spawar.navy.mil/